scientific understanding. Our science policies are important because they will dictate our strategies, our action plans for the necessary scientific research.

> 'Where there is much to learn, there of necessity will be much argument, much writing, many opinions; for opinion in good men is but knowledge in the making.' *John Milton*

At this meeting we shall hear opinion from good men and good women. And let us remember that even if the opinions are diverse, all of us are trying, from different perspectives, to put in place the most useful and productive science policies for our countries.

Can I suggest, as a basis for this meeting, that good science policies are our lifeline to the future.

Let me give two examples of the importance of science policies. The world population continues to expand; human numbers now challenge the ecological sustainability of the planet. 'Farming in the future' (and I quote from Derek Tribe's recent book *Feeding and Greening the World*) 'must aim to increase productivity while minimising the use of scarce resources such as fossil fuel energy, water, capital and land, maximising the use of plentiful resources such as human labour, solar energy, genetic biodiversity and expanding knowledge, and avoiding the contamination, degradation or destruction of the natural environment'.

Good husbandry on the farm within these constraints, will require more and better scientific understanding of plants and animals, soil, water, nutrients, plant and animal health, the harvesting and transport of crops, down-stream processing, food preservation, marketing.

Effective science policies to ensure that the necessary work is done are essential for achieving this goal of increased agricultural production.

Without good science policies, who will ensure that the required scientists and their scientific knowledge are available to the farmer when needed?

My second example is simply a list, but an astonishingly wide list, of the sciences which are critical to the modern food processing industries. These are:

Biopolymer science;
Bio-organic chemistry;
Crystallisation;
Failure mechanics;
Preservation;
Plant cell technology;
Process engineering;
Rheology;
Colloid science;
Nutrition;
Microbial cell biology;
Fluid dynamics;
Molecular modelling; and
Heat and mass transfer modelling.

The food industry will never compete internationally unless all these sciences and technologies are kept alive and well through good science policies which recognise their importance.

Good science policies really are our lifeline to the future.

Where do the scientists themselves fit in? Scientists often expect:

- a high degree of freedom from bureaucratic regulation and interference;
- open communication via international publication;
- close cooperation between institutions and individuals;

and many scientists also request and sometimes demand,

- a major role in determining the direction of their own research.

The tensions between the autonomy of the research scientist and the degree to which programs can or should be formulated by end users, or influenced by the political process, seem to lie at the heart of much that has been happening in science policy in Australia and New Zealand in recent years. I expect that the papers in this afternoon's session will address these and related issues, and now call on our speakers to take the floor.

Sir Arvi Parbo ac fts

SCIENCE AND TECHNOLOGY AND AUSTRALIA'S FUTURE

I am delighted to be invited to participate in this Symposium on Science Policy and I warmly commend the Royal Society of Victoria for organising it. You have assembled a very distinguished group of speakers and I am honoured to have been included.

The Royal Society of Victoria has an impressive record in promoting the advancement of science and its application for the benefit of the people of Victoria. I am pleased to be a member and to have been associated with some of the activities of the Society and the former Sciences Club over the years. Indeed, as I recall, Professor Adrienne

Clarke and Sir Gustav Nossal, who are also speakers at this Symposium, and I between us delivered three successive J. E. Cummins Orations from 1990 to 1992.

When I spoke to the Society in 1991, my topic was 'The Changing Earth'. As a miner, that is a subject I have grown up with and know well. I do not profess to be anywhere near as familiar with science policy, but as the recently elected President of the Australian Academy of Technological Sciences and Engineering I am, through necessity, on a crash course of learning fast!

The Academy's role

The main object of the Australian Academy of Technological Sciences and Engineering (ATS) is, and I quote:

> 'To promote, in the interest of Australia, the application of scientific and engineering knowledge to practical purposes.'

In the field of science and science policy we are therefore at the applied end and include technology. We believe that the practical application of science is essential to our national well-being, and that technological progress, applied in a sustainable manner, is necessary to improve the life of Australians.

If I was to be limited in my comments today to science policy only, I would not feel competent to speak here. With your permission, I would therefore like to include technology and tell you a little about what we in the ATS believe Australia should be doing, and what we in our Academy are doing to help realise the potential benefits of science and technology for the Australian community.

Some questions

Clearly, I cannot in the course of this short address deal with the whole wide field of the place of science and technology in the society. Let me therefore focus on the following questions:

- Do we need a national science (and technology) policy, and what do we mean by it?
- How do we develop community understanding and appreciation of the value of science and technology?
- Can the scientific and technological communities work together in support of national goals?
- How do we develop an innovative culture?
- How do we resolve issues such as the balance between pure and applied research?
- How do we get our best young people to take up careers in science and technology?
- Are we providing the right kind of education in science and technology?

National science and technology policy

Both ends of the political spectrum, science funders, science practitioners, science users, and, indeed, many members of the public, seem to be very much in favour of having a national science policy. At the technology end, the Institution of Engineers, Australia and our Academy in 1992 jointly published a proposal for a national technology policy: copies are available at this Symposium. The joint covering letter by the two Presidents was headed: 'We Must Have A National Technology Policy'.

Such views have been held for a long time. One might then reasonably ask why we don't have such policies or, at least, why many people believe that we don't have them.

The answer seems to lie in the difficulty in defining what we mean by a national science and technology policy. It seems to mean different things to different people:

- To some, it is a national blueprint for setting priorities either within the entire national scientific and technological effort, or within the major sectors of national activity, be they various industries or various disciplines.
- To others, it is simply about defining the best funding arrangements for research.
- To still others, it is about the balance between fundamental and applied research, the mechanisms for capturing for society the benefits from scientific work, attracting the best young people into scientific careers, the arrangements for scientific education, and so on.

Clearly, a national policy must include elements of all these, and more. And clearly also, all these matters are linked with so many other aspects of society that it would be very difficult indeed to produce one all-encompassing document that would stand the test of time in a rapidly changing world. But in casting around for ways to begin, it seems to me that the absolutely essential basis for a national policy is a clear understanding by the decision makers in the community, supported by the community, that science and technology, properly and sustainably applied, is the foundation on which our present and future well-being depends.

When this awareness exists, the other policy aspects follow naturally and can be modified from time to time as required by changing circumstances. Without such understanding, the efforts to formulate a comprehensive policy cannot be successful.

In this context the study under way by Australian Science and Technology Council (ASTEC) entitled *Matching Science and Technology to Future Needs: 2010* could well be a major step ahead in the quest to establish a basis for a national policy. I am delighted to represent the Academy on the Reference Group for this study.

The seesaw

As it is at present, I have to say that I do not think that such a basic community understanding generally exists in Australia today. The high standing of science and technology in the immediate post-Sputnik era has given way to a sense of disillusionment, if not outright hostility.

Professor Geoffrey Blainey, in his book *The Great Seesaw*, identifies a tendency for community beliefs and attitudes to shift and tilt like the movements of a seesaw. He characterises the two extreme positions of society as 'love of nature' and 'love of technology'. He notes that societies wax and wane between these two extremes over time, and that a reversion to nature typically follows a period of frustration with the benefits of technology.

You may recall, as an example, the 'back to nature' movement identified with Jean Jacques Rousseau at the end of the 18th century, which held up the way of life of the 'noble savage' as the ideal. (I understand that Rousseau himself never met a savage in his life, but this did not stop him from pontificating about them. There are parallels here with some of our popular gurus today.)

But Professor Blainey's analysis also concludes that, although technological progress can and does cause problems, it will also help to bring about their solution. No one with even a cursory understanding of how greatly the human condition has been improved by science and technology in the last two hundred years can be in any doubt about this.

Let me give you an important example.

The greatest problem facing the world today is the rapid growth in the world's population. This is the result of the decreasing infantile death rate, the increasing lifespan which in developed economies has doubled in the last 200 years, and the general improvement in the human condition brought about by the revolutionary scientific and industrial progress. Medical science has virtually eliminated the plagues and illnesses which kept the human numbers down until quite recently.

Today we note that the population growth is high in areas where the standards of living are low. Countries with high living standards have negligible population growth. This indicates the likely solution to the problem: as the standards in the rest of the world improve, it can be expected that the growth will slow down and eventually perhaps even reach a plateau. Science and technology, which, because of their beneficial effects to humanity, have caused the problem, are also the key to its solution. Certainly other measures tried so far do not appear to have any chance of success.

Developing community understanding

Why are there doubts about the value of science and technology in the community?

Those of us active in this area tend to assume that the value of what we are doing must be surely self-evident, while various groups in the community have found it useful for gaining publicity, and therefore influence, to concentrate on the real or imaginary ill effects of scientific and technological progress. Such groups, not always constrained by the truth, have been very skilful in capturing the attention of the media with colourful actions and stories and have had a far greater influence on public opinion than the 'quiet achievers'.

We need to become much more active in telling the people in simple words and in an interesting, personalised, and understandable way just how science and technology is benefiting them, and how the adverse side effects of such progress can and are being managed. The current worldwide emphasis on sustainability is now a welcome and essential part of scientific and technological activity. It must provide the answers to the questions which are quite legitimately asked.

We must insist, at all times, on the highest standards of moral and scientific integrity and responsibility in everything we do. Equally importantly, however, we must also tell the public about this.

The point is made very clearly by a verse from a 1914 Broadway play which I happened to see the other day:

The codfish lays ten thousand eggs,
The humble hen lays one;
The codfish never cackles
To tell us what she's done
So we scorn the codfish
While the humble hen we prize.

Recently a new national organisation, Australian Science Communicators (ASC), has been formed, with Julian Cribb as the inaugural President. Its purpose is to bring about broader political and public awareness of the role and contribution of science and technology to our society, its progress, and prosperity. ASC has offered to assist those active in this field in communicating with the public. I believe that this is exactly the kind of development we have been looking for.

We at ATS propose to work closely with Australian Science Communicators and I urge others to do so also. The Royal Society may well decide to take a hand in this.

Powerful new tools for disseminating information such as Internet, home pages, and bulletin boards are now widely in use. The President of the Royal Society, Dr Max Lay, also happens to be the Chairman of our Academy's Technological Information Committee. Perhaps there are opportunities for working together in this area?

A partnership between science and technology

In a recent article the President of The Institution of Engineers, Australia, Dr Ian Mair, said, amongst other things:

> 'For too long, the engineering work force has been content to leave the leadership of the country to the political process. This process has failed to imbue ordinary Australians with a confidence in their abilities. We live for the present, spending $105 for every $100 we earn as a nation. This is not sustainable.
> 'We can wait no longer. The Council of the Institution of Engineers has endorsed public-interest issues that it will be joining debate on this year. The issues include public infrastructure, water resources, health, the environment, and information technology. Other issues to be addressed will be the innovation process and engineering education.'

I believe that The Institution is showing the kind of leadership that is needed and I welcome this as a Fellow of the Institution, as well as on behalf of our Academy. The Institution will have our full cooperation in areas in which we are competent, particularly as we are the Academy of Technological Sciences and Engineering and some one third of our Fellows are also Fellows of The Institution of Engineers. We have worked together in the past—I have mentioned the proposal for a National Technology policy—and we look forward to doing so even more actively in the future.

Similarly, we offer our cooperation to other scientific and professional bodies. We already consult regularly with our sister Academies of Science, Social Sciences, and Humanities through the Consultative Committee of Australian Academies. We were recently pleased to be associated with the Academy of Science and the Academy of the Social Sciences in a major review of Climate Change Science, with many organisations, including the Institution of Engineers, participating on the Steering Committee.

The boundaries between science and technology have always been unclear and are rapidly becoming more so. More than that, science, technology, and the social sciences are beginning to overlap. We do not believe that there are any reasons for rivalries between organisations in these areas, and that there is every reason for full cooperation in the interests of Australia.

An innovative culture

My predecessor as President of ATS, Sir Rupert Myers, often stressed that our greatest need in Australia is to develop and foster a spirit and culture of enterprise. He recently wrote:

> 'Australians have a history of adopting new technological hardware in their everyday lives. We are among the quickest in the world to buy new gadgets for our home and for our transport, communication, education, and recreation needs. We take pride, too, in seeing Australians discover new scientific things and ideas. We are, alas, not so quick or adept at translating those discoveries into profitable enterprise.
> 'There is a need to harness our positive attributes to foster an enthusiasm for enterprise and innovation. We need to persuade the young, and others, that it is worthy and admirable to have ideas for making and doing things and then to be enterprising by bringing together skills, materials and methods for doing this profitably and for the benefit of consumers and the community. It is worthy to become an entrepreneur and not just an employee.'

I agree completely with Sir Rupert and I hope that we all, The Royal Society, the Academies, professional bodies, other organisations, and we all as individuals, will do all we can to help introduce this culture into Australia. ATS is delighted that the Minister for Industry, Science and Technology, Senator Peter Cook, is at present leading a major Federal Government campaign in this area and we are pleased to assist in this.

Balance between pure and applied research

One of the perennial issues in debate is the balance of effort and resources between so-called 'pure' or 'basic' and 'applied' research, between 'research' and 'development', between 'R&D' considered generically and 'commercialisation', or 'application'. It is frequently asserted, and I have no reason to differ with this observation, that Australia is doing well in research but that, when it comes to capturing the economic benefits of that research, we do not do nearly so well.

The ATS has repeatedly and consistently argued the need for a greater effort in this area, and I agree wholeheartedly. This is a task which, like so many others in the commercial world, is never 'done': there is always room to improve, to do better, to exceed our previous best. I would not, however, like this to be taken to mean that our record in commercial applications is wholly poor, or that we should not strive to maintain our proud national record in basic research.

I believe that our rural industries have been remarkably successful in making practical use of our research achievements in this area. I know from personal knowledge that in the minerals industry we have been equally successful in building linkages between the research community and industry. We have excellent communications with the Universities, the CSIRO, the former Bureau of Mineral Resources (now the Australian Geological Survey Organisation), and some particularly effective cooperative interface mechanisms such as the Australian Mineral Industries Research Association (AMIRA). When mineral and petroleum exploration is included as research—which it is—the industry is not only spending heavily on research, but can show excellent returns from this spending.

It is relevant to note that three of the four recipients of this year's Australia Prize in the field of remote sensing were supported in their prize-winning work by companies in the Australian mineral industry. I am proud to say that one of the winners was a Fellow of our Academy.

But the benefits from research do not occur only in the industrial sector. There are fields in the public domain where our record is up with the best in the world. For example, Australia's achievements in weather and climate research and in oceanography and hydrology and the translation of that research into benefits to the national economy is outstanding.

Turning now to the balance between basic and applied research, I know that there is much concern in the scientific community that the recent emphasis on immediately useable science may be putting at risk what some, at least, see as one of our real sources of competitive advantage, namely our longstanding tradition of excellence in basic research. I understand that these issues got a public airing recently during the visit to Australia by the editor of *Nature*, Sir John Maddox, who has become increasingly vocal in supporting continued commitment to basic research in the UK.

I cannot visualise that anyone would seriously argue that Australia should not do any basic research. The debate can be only about the proportion of the total effort that goes into either area. Is it too simplistic to say that the effort going into applied science must be such that it enables the economy to grow at a satisfactory rate, thus making more total resources available and therefore more for both basic and applied research? To put it the other way, if our economy does not grow sufficiently, less will be available for research of any kind.

May I be permitted another simplistic question? Because it is so difficult to define better measures, we generally use the funding available as the criterion of the adequacy or otherwise of the research effort. But surely what matters is not how much we spend, but what we produce. What really matters is not the funding, but the results from the funding. Is it possible to develop measures of the output, rather than of the input?

I am sure that others today, more knowledgeable in these matters than I, will pursue this topic further. Our view in ATS is, that it is a very important issue, that both basic and applied research are essential to our future, and that any decisions on the balance between them should be made on a rational and objective basis.

Attracting young people into science and technology

Encouraging our best young people to take up careers in science and technology is in my view closely related to creating better public awareness

and understanding of the role and importance of such activities to the community. If science and technology are high in public esteem, young people will want to be involved. If they are not highly regarded, it is understandable that young people will seek careers in other areas. The points made earlier under the heading 'Developing Community Understanding' are therefore directly relevant here.

Initiatives such as the Australia Prize, established by the former Minister for Science and a Fellow of our Academy, the Hon. Barry Jones, are very valuable in this context.

Education for science and technology

While not an expert, I have heard enough informed comment on this topic to be convinced that there is no uniquely 'right' model for education and training in this area.

Science and technology have not been attracting large numbers of high quality students and there have been suggestions of increasing pressures to modify the rigorousness of the courses to maintain enrolments. If true, this would be a matter for very serious concern. We need more rigorous, not less rigorous, training to meet the demands of the future.

A major review of engineering education is about to commence, conducted jointly by the Institution of Engineers, Australia, as the professional and accrediting body, the Australian Council of Engineering Deans, and the Australian Academy of Technological Sciences and Engineering. It is to report in 15 months. Similar reviews have been previously conducted in other areas. Jointly, their conclusions must form an important part of any national science and technology policy.

The Academy

Let me conclude by commenting further on the Academy of Technological Sciences and Engineering.

Established in 1975, its 470-odd Fellows come from all branches of technological sciences and engineering and represent the top achievers from academia, government, and industry in their fields. Their work on behalf of the Academy is on a voluntary basis through a number of Committees, Task Forces, and Study Teams of Fellows and others. There are Divisions of the Academy in all States.

We are frequently asked to express our views on various matters within our competence which are under review or study by the Federal government. We conduct symposia and seminars on issues of particular interest. Standing Committees include Education for Technological Sciences and Engineering, International Relations, Technological Information and Sustainable Development.

We undertake major projects of study and inquiry; time prevents me from elaborating on these. Some of these projects have been mentioned earlier. The report on the most recent study on Climate Change is available at this Symposium. Please take one and read it. It has been widely distributed in Australia and overseas, including to all secondary schools and municipal libraries in Australia. It is an authoritative, impartial, and objective summary of the present scientific understanding and the uncertainties in this very important issue.

One ongoing Academy project which has been very successfully operated for more than five years and has been extended for a further five years is the Crawford Fund for International Agricultural Research, which enables professionals from Australia and from other countries, mainly in Asia, to learn about the agricultural practices and technology developed in Australia, and to form linkages between Australian and overseas agricultural professionals and organisations. Added to it this year has been similar training in biotechnology. The activities of the Fund are highly recognised internationally and supported by the Australian Government and private industry.

But the international dimension of the Academy's work extends further.

The Academy is a founding member of the Council of Academies of Engineering and Technological Sciences (CAETS) which links together 15 like Academies, so far mainly in Europe and North America. This provides valuable links to technological developments in these areas. The International Relations Committee conducts bilateral programmes with like Academies in countries in our region. Thus, for example, we have active exchange programmes, involving workshops, in targeted areas with China, Korea, and Taiwan (the latter two in association with the Australian Academy of Science). We are developing links with Indonesia, Thailand, Malaysia, and the Philippines and are assisting in the formation of like Academies where these do not currently exist. We believe the benefits of scientific and technological exchanges are mutual and often lead to commercial linkages.

Conclusion

I hope that these brief observations and the wilful addition of technology to your topic of science

policy have been of some value. I regret that a commitment in Sydney this evening prevents me from participating fully in this Symposium, but let me assure you that this is not because of lack of interest. I look forward to hearing in due course about the conclusions.

Allow me once again to assure you of the full cooperation of the Academy of Technological Sciences and Engineering in any areas which lie within our competence.

PROFESSOR ADRIENNE E. CLARKE AO FTS FAA

SCIENCE, TECHNOLOGY AND AUSTRALIA'S FUTURE

1. Science Policy in Relation to our National Goals

Achieving a strong capability in S&T is a necessary, but not sufficient, part of a strategy for achieving our National goals, which fall into three groups:

- economic prosperity;[1]
- environmental welfare; and
- social, cultural and welfare issues.

Indeed, innovation—particularly technological innovation—is widely viewed as a key driver of the economic prosperity of nations. At this time in the history of the world, science is pervasive in human affairs.

Economic prosperity

Economic prosperity is a goal not only of the business groups; it is acknowledged as important by many environmentalists, and at least by inference by welfare organisations who see the destructiveness of unemployment and inadequate resources.

Looking ahead to 2020 it is likely that the main bases of wealth creation will be in:

- resource-based industries;
- high value-added manufacturing and services industries; and
- new knowledge-based and information-intensive industries.

Our science and technology capabilities, underpinned by our standards of education and training, will be crucially important to success in all these areas. Increasingly our goods and services are differentiated by their S&T content.

Environmental welfare

We must be careful, much more careful than in the past, to prevent economic activity destroying our air, polluting our water or damaging our genetic resources. We have to protect, indeed restore, productivity of our soils. Our quality of life certainly includes visual and environmental amenity. We have a wonderfully diverse biota in Australia, which we must conserve for our own profit and pleasure and for that of future generations.

Again science and technology is absolutely critical to achieving an improved environment. As we establish more knowledge about our ecosystems, we are better able to achieve higher levels of sustainable development. Our overall welfare will not be improved by negative, zero, or even slower rates of economic growth.

Social, cultural and welfare issues

Our lives are being radically changed by the revolution in media and information technology. Information and capacity for education will, within a short time, become more generally accessible, and there will be a variety of new means for cultural expression and communication. The creative potential being unleashed by such things as new technologies at the theatre and by new materials in the plastic arts is quite staggering. In the health sciences the contribution of science and technology to the relief of human suffering, extension of life and improved quality of life for the handicapped is evident in many families.

It is critically important that we care for the less fortunate members of society by spreading wealth through the taxation and then the welfare system. This requires that we generate sufficient wealth to spread.

- Policy issues centre on long term planning to attract investment—to capture our share of global wealth.

  This includes:

  1. Maintaining and enhancing our long-term capability in S&T.
  2. Learning to capture the value from our investment in S&T.

2. Factors to Consider in Formulating Tactics for Implementing a Strategy of Maintaining a Strong Capability in S&T

Many Australians, including many of our decision-makers, have a very hazy idea of what